Aerosol EnKF at GMAO

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Introduction

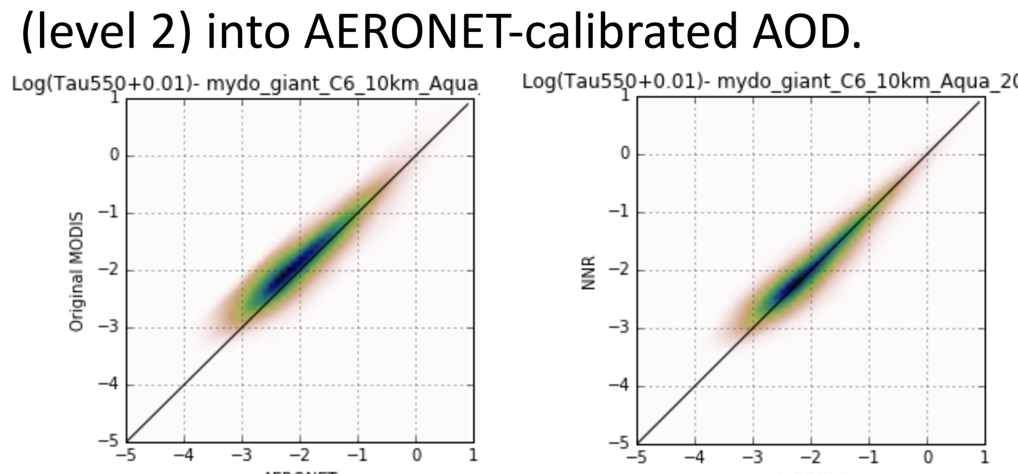
In the GEOS near real-time system, as well as in MERRA-2 which is the latest reanalysis produced at NASA's Global Modeling and Assimilation Office (GMAO), the assimilation of aerosol observations is performed by means of a so-called *analysis splitting* method.

In line with the transition of the GEOS meteorological data assimilation system to a hybrid Ensemble-Variational formulation, we are updating the aerosol component of our assimilation system to an ensemble square root filter (EnSRF; Whitaker and Hamill (2002)) type of scheme.

We present a summary of our preliminary results of the assimilation of column integrated aerosol observations (Aerosol Optical Depth; AOD) using an Ensemble Square Root Filters (EnSRF) scheme and the ensemble members produced routinely by the meteorological assimilation.

Aerosol observations (NNR retrievals)

The assimilation of Aerosol Optical Depth (AOD) in GEOS involves very careful cloud screening and homogenization of the observing system by means of a Neural Net scheme that translates cloud-cleared observed MODIS C6 radiances (level 2) into AERONET-calibrated AOD.



AOD is two-dimensional and constrains the *total column optics* of aerosol, NOT the aerosol speciation or vertical distribution.

Aerosol assimilation

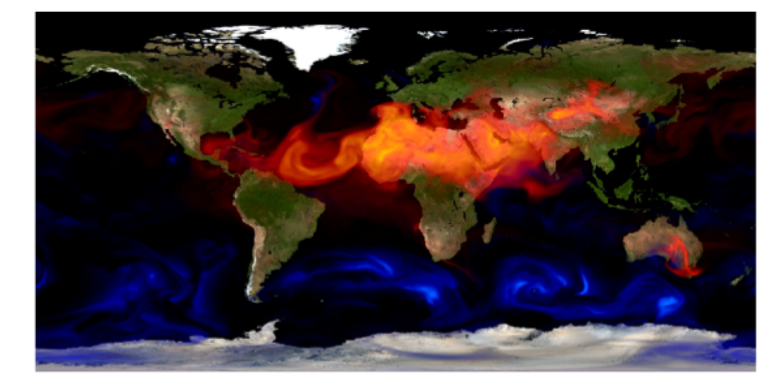
Current method (analysis splitting scheme):

- First a 2D analysis of AOD is performed using error covariances derived from innovation data. The AOD analysis increments are computed using a 2D version of the Physical-space Statistical Analysis System (PSAS, Cohn et al. 1998). The 2D analysis is performed using the natural log-transformed AOD at 550 nm as control variable.
- GOCART simulates aerosol mass, so AOD analysis increment must be translated from an optical quantity to mass using the relative speciation, vertical distribution, parameterizations *etc.* from the model. Then 3D analysis increments of aerosol mass concentration are computed using an ensemble formulation for the background error covariance. This calculation is performed using the Local Displacement Ensemble (LDE) methodology under the assumption that ensemble perturbations are meant to represent misplacements of the aerosol plumes (More details in Randles et al., 2017).

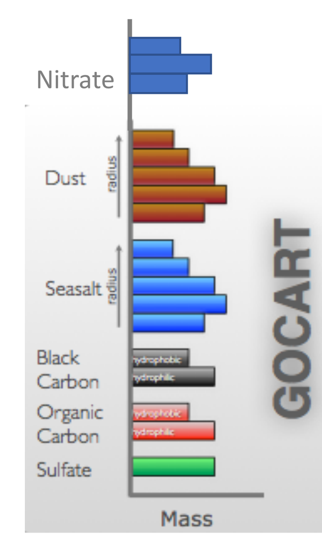
EnSRF framework for aerosols:

- EnKF code from Whitaker and Hamill (2002) used for the hybrid meteorological assimilation adapted for assimilating 2D aerosols observations (bias-corrected log(AOD + 0.01) at 550 nm).
- 32 members available every 6 hours at a nominal 100km horizontal resolution for the results presented here.
- Quality control (buddy-check of Dee et al. (2001)) of AOD observations is performed on the ensemble mean and allows each member to see exactly the same set of observations.
- Analysis in term of AOD or in term of aerosol mass mixing ratio.

Aerosol model



The prognostic model is based on the GEOS model radiatively coupled to GOCART aerosol module (Colarco et al, 2010) and includes assimilation of bias-corrected Aerosol Optical Depth (AOD) at 550 nm from MODIS sensors.



GOCART treats the sources, sinks, and chemistry of 18 externally mixed aerosol mass mixing ratio tracers: dust (5 non-interacting size bins), sea salt (5 non-interacting size bins), hydrophobic and hydrophilic black and organic carbon (BC and OC, respectively), nitrate (3 bins) and sulfate.

The prognostic variable in GOCART is the 3D aerosol mass mixing ratio for each species.

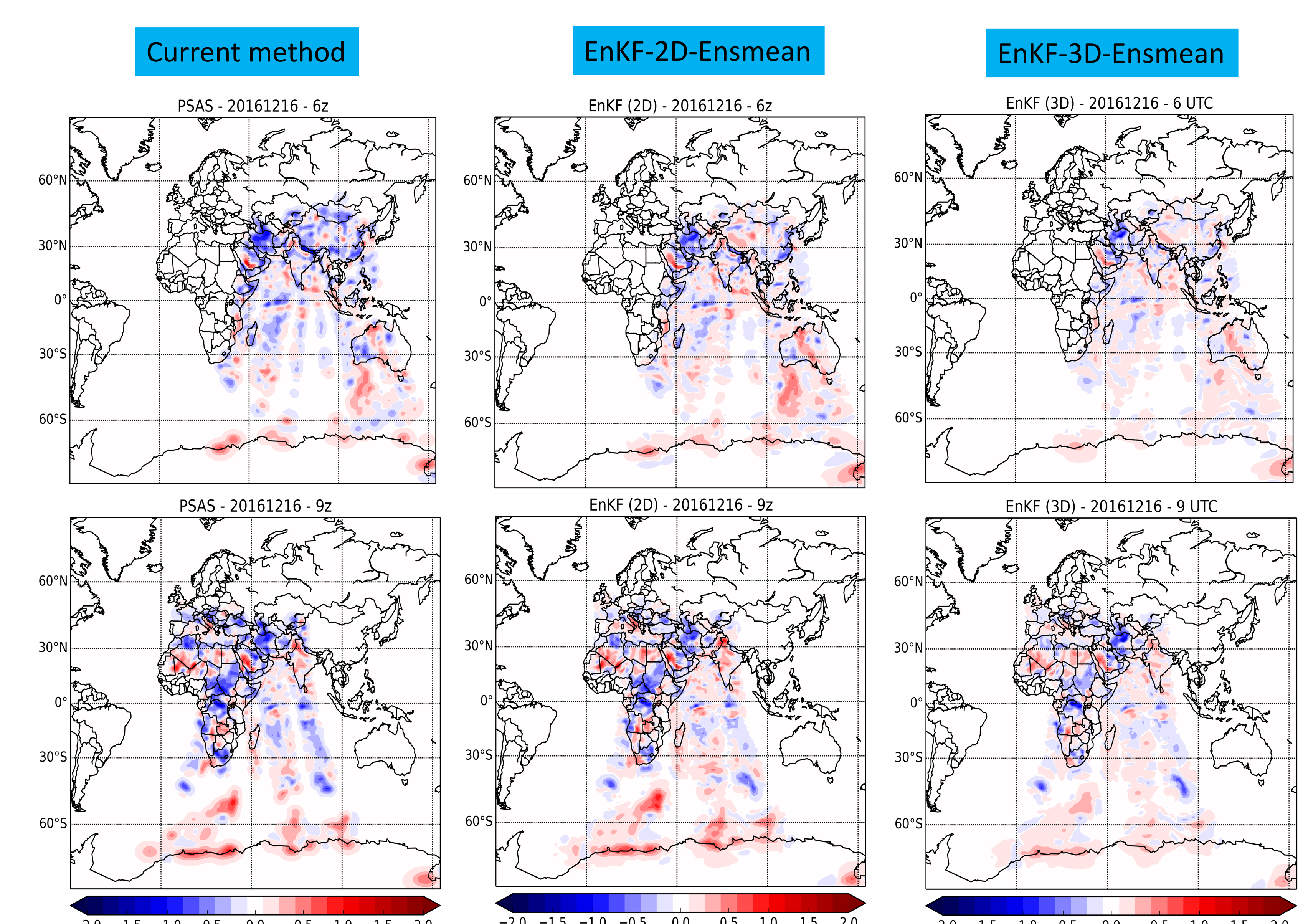
AOD is 2D and is defined as the integrated aerosol extinction coefficient over a vertical column of unit cross section,

$$\tau = \beta_{ext} \bullet \text{Mass}$$

B_{ext} depends on aerosol optics (index of refraction, size distribution)

Results

AOD analysis increments – 16 December 2016 at 6UTC (top) and 9UTC (bottom)



Here, the impacts of using the EnKF approach (in 2D and 3D) are demonstrated by comparisons to the current AOD analysis increment (PSAS) at 550 nm on two different times.

The EnKF analysis is done in term of log(AOD) (middle) or in term of aerosol mass mixing ratio (right). For this last case, the AOD increment is calculated by doing a difference between the AOD computed from the 3D aerosol analysis mass minus the AOD computed from the 3D aerosol background mass for the ensemble mean. EnKF-based scheme (2D and 3D) recovers AOD increment values in the same order of magnitude as PSAS and at similar locations for both time.

Conclusions

- EnKF framework development for assimilation of 2D aerosols observations (AOD) advanced,
- Preliminary results encouraging, EnKF-based scheme recovers AOD increments in the same order of magnitude and at similar locations than PSAS.

Future work:

- Increasing spatial resolution of the members,
- Tuning of the observations errors,
- Adding more observation types:

Multi-wavelength AOD, 3D information from lidar observations (CALIOP/CATS) to better constrain the aerosol speciation and vertical distribution.

References:
Colarco, P., A. da Silva, M. Chin, and T. Diehl, 2010: Online simulations of global aerosol distributions in the NASA GEOS-4 model and comparisons to satellite and ground-based aerosol optical depth. *Journal of Geophysical Research*, 115 (D14207), doi:10.1029/2009JD012820.
Dee, D. P., L. Rukhovets, R. Todling, A. M. da Silva, and J. W. Larson, 2001: An adaptive buddy check for observational quality control. *Quarterly Journal of the Royal Meteorological Society*, 127, 2451–2471, doi:10.1002/qj.49712757714.
Randles, C. A., A. da Silva, V. Buchard, P. R. Colarco, A. S. Darmenov, R. C. Govindaraju, A. Smirnov, R. A. Ferrare, J. W. Hair, Y. Shinozuka, and C. Flynn. The MERRA-2 Aerosol Reanalysis, 1980-onward, Part I: System Description and Data Assimilation Evaluation. *J. Climate*, 2017.
Whitaker, J. S. and T. M. Hamill, 2002: Ensemble data assimilation with perturbed observations. *Mon. Wea. Rev.*, 130, 1913-1924.